Optics Med.

Vol. 21, No. 12 DECEMBER 1944

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Published Monthly by the AMERICAN JOURNAL OF OPTOMETRY PUBLISHING ASSOCIATION.
1501 Foshay Tower, 821 Marquette Ave., Minneapolis 2, Minn.

ANNUAL SUBSCRIPTION $4.00 CANADA $4.50, FOREIGN $5.00
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Publication Office: 1501-04 Foshay Tower, 821 Marquette Av., Minneapolis 2, Minn.

AMERICAN JOURNAL OF OPTOMETRY
and ARCHIVES *of*
AMERICAN ACADEMY OF OPTOMETRY

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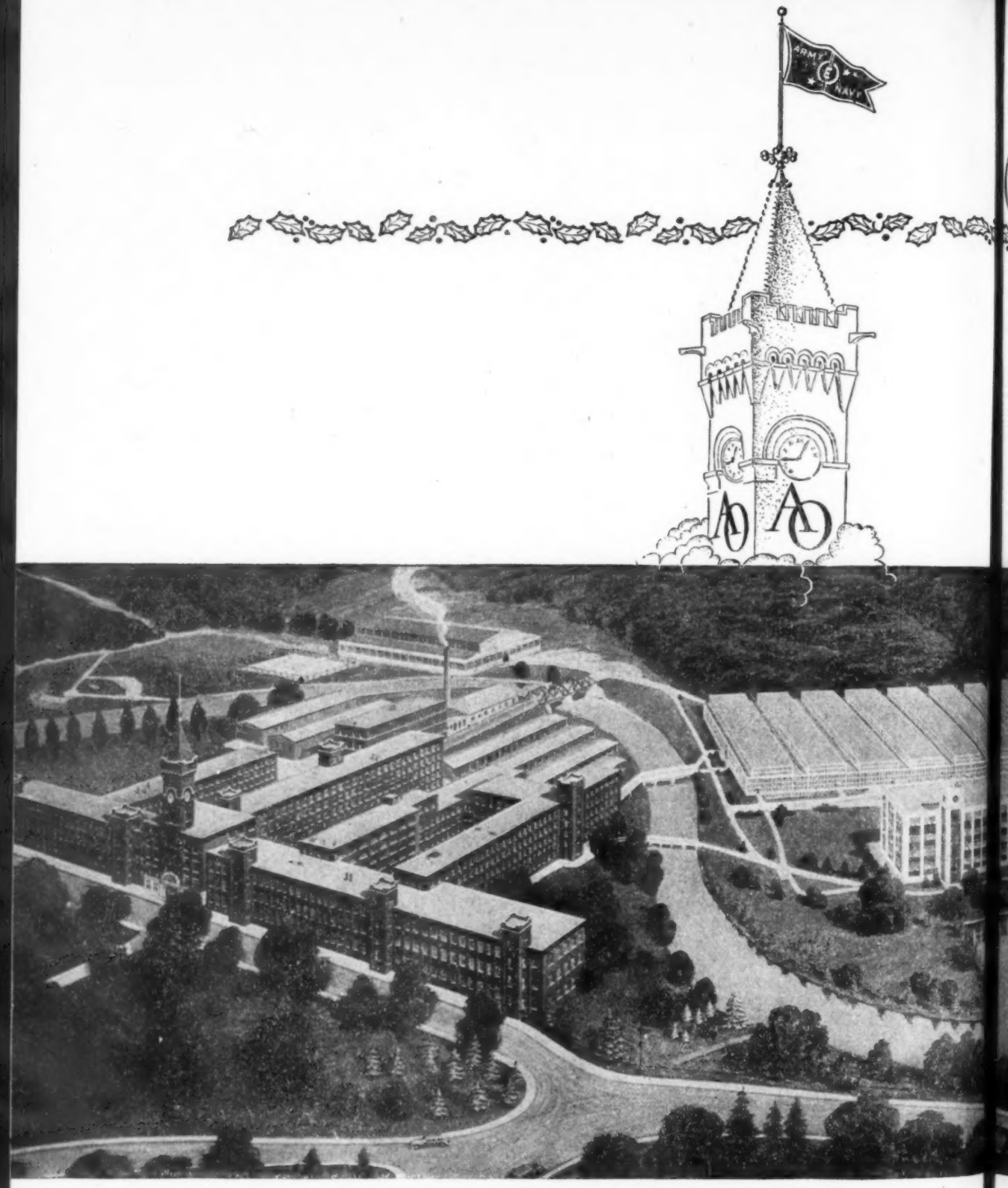

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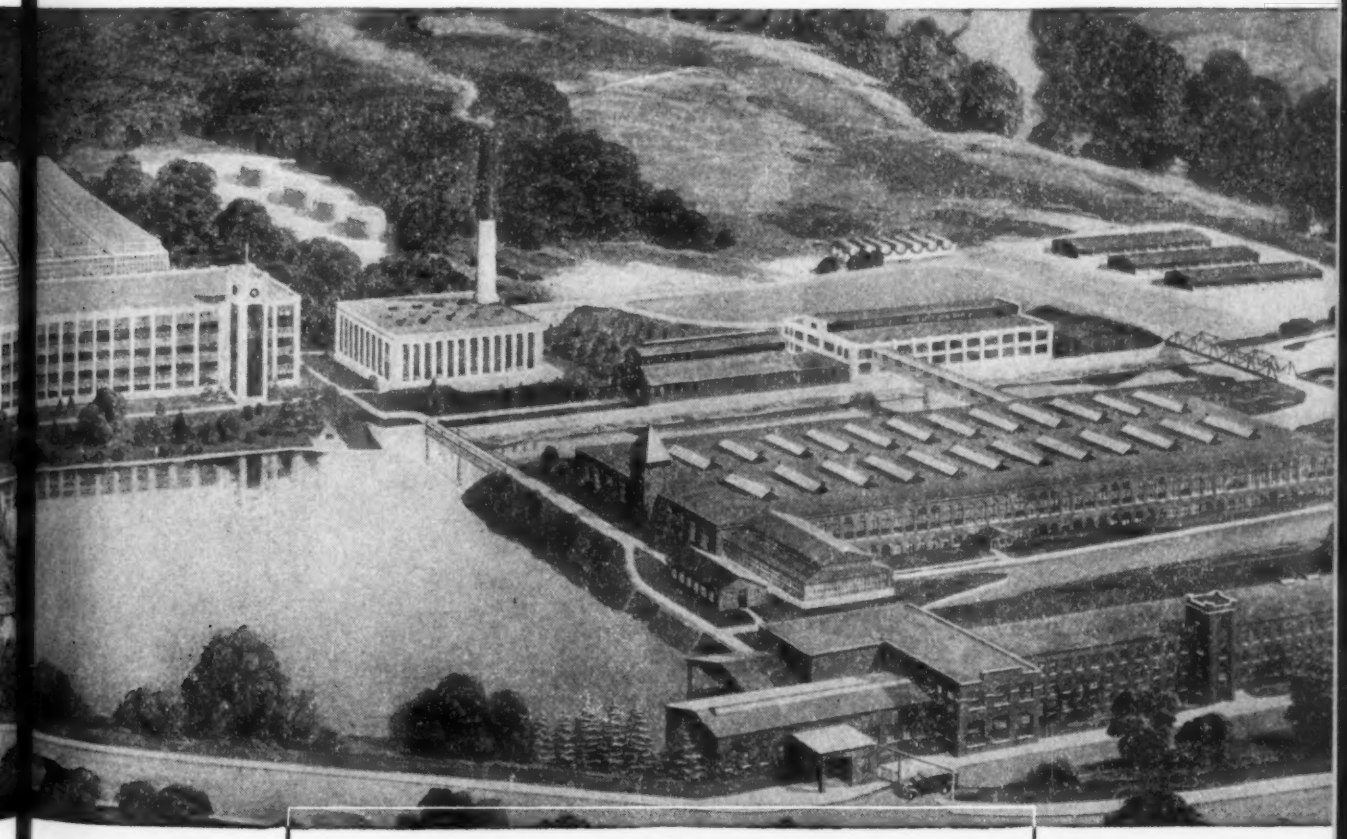

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Vol. 21, No. 12 December, 1944

ANALYSIS OF CLINICAL DATA *

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In previous papers a report of investigations as to the nervous control of accommodation,[1] laboratory measurements of accommodation and convergence,[2] and a statistical analysis of clinical measurements of these same functions[3] has been made. This paper will deal with the development of logical interpretation of clinical data as well as a report on attempts to change clinical findings by means of orthoptics.

Historically there have been a great many analyses of clinical data. A resume of all these, even if it were desirable, would become a book of many pages. Since some sort of line must be drawn, only those analyses which have contributed, in the writer's opinion, to a marked degree to the concepts of present day optometry will be considered.

Today the direct influence of Donders[4] except for his classical measurements of the amplitude of accommodation is scarcely felt. Landolt's[5] influence has likewise faded with time. As has already been mentioned in previous papers [2, 3] Maddox[6] was the first to state a rational theory of convergence, accommodation and the relationship between them which is upheld by careful modern investigation. While it was really Maddox who advanced the conceptions dealing with the use of both eyes acting together in perfect concert as though they are one, it was Percival[7] who first realized and advocated a practical application of Maddox's ideas. Percival's great contribution is in connection with what he called the "Zone of Comfort." Sheard[8] concurs with Percival and the two men have influenced optometric thinking to a great extent. The "Zone of Comfort" is the middle third between opposing functions such as adduction and abduction, P.R.C. and N.R.C., and P.R.A. and

* Submitted on October 4, 1944, for publication in the December, 1944, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

N.R.A. For example, suppose that through the subjective finding a non-presbyopic patient has a P.R.A. of —3.00D and a N.R.A. of +2.25D. The total of these functions is 5.25D. Therefore ⅓ of the total range is 1.75D and this amount deducted from the two limits shows the middle third or zone of comfort to be between the limits of —1.25D and +0.50D. Now since zero falls between these limits; that is the subjective finding with no added lenses in place, this patient should be comfortable as far as the function of relative accommodation is concerned. On the other hand, suppose this subject had a P.R.A. of —1.00D and an N.R.A. of +3.50D. The zone of comfort now has the limits of +0.50D and +2.00D. Now in order to place this subject's relative accommodation functionally within the limits imposed by the idea of the "Zone of Comfort" a minimum addition to the subjective of +0.50D is required.

It is at once apparent that this thesis of Percival and Sheard is more concerned with the correction and alleviation of visual malfunctioning than it is with the analyses of what is causing the basic disturbance. It assumes that each function measured is a descrete entity which may or may not have any necessary relationship with any other measured function.

In recent years perhaps the greatest influence on optometric thinking is exerted by the Optometric Extension Program. The writer realizes that here he is entering upon dangerous grounds since, if he criticizes the program he will at once be classed as an "anti," or if he doesn't criticize, he will be classified as a "pro." This is largely due to the fact that the movement is not a pure and simple educational system but is political to a great extent. On the other hand, if anyone who is interested in research and education just ignores the program without recognizing its tremendous influence on optometric thinking, he is either dull or ostrich-like with his head buried in the sand of his own making. The writer's interest in the O.E.P. is purely academic and is no more nor less intense than his interest in the ideas already advanced by Landolt, Maddox, or Sheard which have influenced optometrists.

The scheme of case analysis now promoted by the O.E.P. grew out of the desire to classify subjects by means of the data taken in a routine clinical investigation of visual functions. The main thesis being that all measured functions are related to all other functions in some way so that in a normal subject, for example, if you change the amount of accommodation to see a particular target by the use of convex or concave lenses, changes occur not only in accommodation but predictable changes occur in convergence. Since all functions are interrelated it is

therefore logical to assume that if some are found to be low others must be high and vice versa. From this the next logical step is to draw up a series of possible combinations or syndromes into which measurements will fall. Now since we must know definitely whether a particular function is high or low some standard of measurement for each function must be derived. These so-called "expecteds" are apparently averages of measurements for all age levels. The theory of the interrelationship of the various measured functions is based on the assumption that there is always 2.50D of accommodation in subjects with more than 5.0D of accommodation ideally associated with 15△ of convergence. Phorias and relative functions measure "zones of play" between the two functions. The most lucid and readily available account of this particular system of "analytical refraction" is to be found in Dvorine's book, "Analytical Refraction and Orthoptics."[9] Essentially then, three ideas are found in this particular analysis:

1. Functions are interrelated through the association of accommodation and convergence.

2. Due to this association the syndrome method of analysis can be made.

3. Functions are either high or low depending on how they vary from a set standard for each measurement, the so-called "expecteds."

For several years the particular "expecteds" and syndromes as advocated by the "Graduate Clinic Foundation" and Skeffington in particular were apparently accepted by the "pros" and totally rejected by the "anti's" without either side justifying their arguments by evidence. Then in 1941 Haines[10] published his paper reporting on his clinical investigations at Ohio State University. He accepted the idea that certain normal values or "expecteds" should be found for each test and that syndromes could be arrived at so that patients could be classified into several rather distinct groupings. His normal values were used from a slightly different point of view than previously in that they set up a series of minimum requirements. Haines' conclusions were based on the statistical analysis of clinical data. On the whole, his analysis advocates a less rigid analysis than that advocated by the O.E.P.

Starting in 1940, Shepard[11] began to publish a series of articles dealing with the statistical analysis of data. These papers have dealt to a large degree with the development of an acceptable series of normal findings and with an attempt to arrive at some basis by which to judge the accuracy of each measurement. This latter point is well taken for it is

obvious that a strict interpretation of a test which is not accurate within wide limits is foolish.

In a similar manner Betts and Austin[12] have investigated by statistical analysis the clinical data of sixth-grade school children.

In a previous paper[3] the writer has discussed his statistical investigation of clinical data of prepresbyopic subjects.

Every scientific hypothesis must be examined critically to see whether or not it offers an explanation of all observable phenomena. These hypotheses are generally arrived at either by a philosophical approach in which little or no investigation precedes the establishment of the theory or by an attempt to explain carefully arrived at data in a logical manner. The first method is probably the most common, since it is the easiest. These hypotheses, however, are less reliable but also, fortunately, they are the easiest to break down since they are characterized by no published research data and an excess of verbiage to overcome the lack of facts.

It has been shown [2, 3] that accommodation and convergence are related through accommodation. Thus every time accommodation changes there is a proportional change in accommodative-convergence over the whole range of accommodation. This means that it is impossible to change accommodation without influencing convergence. On the other hand, there is a relative range in convergence such that between rather definite limits, differing for each subject, convergence may be changed without influencing accommodation. However, if convergence is varied beyond these limits, accommodative-convergence may or may not come into play to assist convergence. It is to be noted that this is not a distinct function, convergence-accommodation, but accommodative-convergence.

This point deserves special emphasis. It seems that the ability to stimulate accommodation and thus stimulate accommodative-convergence to aid convergence or the reverse ability of inhibition is a learned function. Some people learn to do this, while others do not. This is shown by the fact that only in about 40% of all subjects tested do we find blur-break-recovery in all relative convergence tests. Frequently diplopia occurs before blurring. As has already been indicated in a previous paper,[2] there are four general categories of subjects:

1. Blurring occurs in both positive and negative relative convergence measurements.
2. Blurring occurs in only the positive measurements.

3. Blurring occurs in only the negative measurements.

4. Blurring occurs in neither positive nor negative measurements.

The presence or absence of blurring is an indication of whether or not a particular subject has learned to utilize accommodative-convergence to aid fusional convergence in increasing the amplitude of these functions.

It seems obvious that in normal functioning of the eyes the part of convergence that is of primary interest is that part free from accommodation. Subjects who have either a low positive or low negative fusional convergence may easily be taught to utilize accommodation to increase either of these functions. Sometimes this is desirable, but most frequently it is not. Therefore, the optometrist must carefully consider these functions in planning and giving orthoptics or in prescribing lenses.

Fortunately, relative convergence and fusional convergence when they are different in value do tend to vary together, so that both are generally either normal or higher or lower than normal at the same time. Most frequently the results of the analysis of a particular case is not changed if one considers just fusional convergence and does not take into account relative convergence. However, there are times when the two functions differ materially and in any event for a full analysis of accommodation and convergence both functions should be measured.

Thus a phoria measurement, aside from owing its amount to the instrument used, is a measure of the influence of numerous factors on the direction of the visual lines: the anatomical arrangement of the extraocular muscles, the tonicity of the muscles at the moment of measurement, the state of accommodation, the psychic influence of the subject's judgment as to the distance of the fixation target, and the influence of peripheral fusion. When a true phoria measurement is made, it is possible to make certain of these factors a minimum. Positive accommodation can be reduced by using a distance fixation target and lenses. The influence of peripheral fusion and psychic convergence may also be reduced by using the Maddox Rod technique in a dark room; the measurement being made with a modified cover method as already described in a previous paper.[3] On the whole, therefore, a phoria measurement by itself is very complex and cannot be strictly analyzed but it may be thought of as giving a good idea of the amount that fusional convergence must contribute to general convergence in maintaining fixation. When the test is made at some near distance, accommodation and hence accommodative-convergence becomes active and the function becomes even more complex. Since accommodation is definitely known to be active above its tonic

level, the measurement can no longer be termed a phoria. The term used by Sheard is the most descriptive of the test, a measure of fusional supplementary convergence.

As indicated above, a phoria is not a simple thing. Regardless, however, of those factors which go to make up a phoria it does indicate how much fusional convergence must be utilized in maintaining clear and single binocular vision, hence it is a measure of how much convergence must be supplemented by fusional convergence, hence fusional supplementary convergence.

The gradient test is a measure of accommodative-convergence and can be used to indicate the extent to which accommodative-convergence is active.

The prism blur tests are indicative of the relative range of convergence in which accommodation is not influenced. The actual measurements are too high because accommodation becomes activated before blurring occurs. However, the rate of change in accommodation is relatively rapid when compared to the rate of change in convergence; hence, the amount of error is usually small. In cases where diplopia occurs before blurring, the diplopia point represents the end point of this function. This indicates that under the conditions of the test this subject does not utilize accommodative-convergence to assist relative convergence.

Both dynamic skiametry and N.R.A. are measures of negative accommodation for a fixed amount of total convergence regardless of possible changes in the component parts of this total convergence. Obviously as convex spheres are added accommodation becomes less and hence accommodative-convergence becomes less. If binocular vision is to be maintained, then positive relative convergence must be stimulated. Thus the results obtained by dynamic skiametry are dependent on first the total amount of accommodation available and secondly the amount of P.R.C. available. As a rule, accommodation determines the end point.

The subjective measurements of possible changes in positive and negative accommodation with a fixed amount of convergence are poor as far as using them as absolute values of a quantitative nature since they give results in stimulus values and not in response values. This same objection does not hold in case of dynamic skiametry.

Obviously in any series of measurements some sort of standard must be set up. As a rule, statisticians accept as normal any measurement that falls in the range mean $\pm$ approximately 0.7 standard deviation. However, since the mean $\pm$ S.D. as reported in Table I includes a greater

percentage of subjects than is normal, arbitrary limits may be set at ±0.5 S.D. as shown in Table 1.

TABLE 1

Test	Mean	S.D.	% Included	Arbitrary Range
Phoria	1△EXO	±2△	76%	Ortho to 2△EXO
Adduction				
Blur	9△	±4△	69%	7△ to 11△
Break	19△	±8△	80%	15△ to 23△
Recovery	10△	±4△	74%	8△ to 12△
Abduction				
Break	7△	±3△	81%	5△ to 9△
Recovery	4△	±2△	70%	3△ to 5△
Dyn. Skiam.	+1.37D	±0.37D	78%	1.25D to 1.50D
Mon. X Cyl.	+1.00D	±0.50D	72%	0.75D to 1.25D
Bin. X Cyl.	+0.50D	±0.50D	87%	+0.25D to +0.75D
Fus. Sup. Conv.	—3△	±5△	76%	Cent. to —6△
P.R.C.	17△	±5△	64%	no blur or 14△ to 20△
P.F.C.				
Break	21△	±6△	80%	18△ to 24△
Recovery	11△	±7△	76%	7△ to 15△
N.R.C.	13△	±4△	58%	no blur or 11△ to 15△
N.F.C.				
Break	21△	±4△	80%	19△ to 23△
Recovery	13△	±5△	75%	10△ to 16△
P.R.A.	—2.37D	±1.12D	74%	—1.75D to —3.00D
N.R.A.	+2.00D	±0.50D	73%	+1.75D to +2.25D
Gradient	—4△	±2△	84%	—3△ to —5△
Amplitude	Age*	±2.00D	82%	Age ± 1.00D

It is possible from such a table as Table 1 to find out first if any function is lower than the average or mean value. Just on chance alone if there is equal distribution around the mean, at least 50% of all subjects should have findings lower than the mean and 50% higher than the mean. Therefore, after noting whether a finding is high or low as compared to the mean it is necessary to find out how high or low it is. For example, suppose a subject has a P.R.C. of 15△. This is lower than

*Duanes tables.

the mean for this function, but it is within the normal limits. There is a definite possibility then that this function may be low, it is probably not high, but it may be normal. A similar check on each measured function should be made.

The possibilities of setting up a series of syndromes depends to a large degree on the relationship between the various tests. These relationships were calculated and published in a previous paper.[3] If now one takes these coefficients of correlation and works out all possibilities without regard to the degree of relationship, it is possible to find that the following tests are related in some degree to each other: fusional supplementary convergence, P.R.C., N.R.C., dynamic skiametry, P.R.A., N.R.A., Bin. X Cyl., Mon X Cyl., P.F.C., and N.F.C. This relationship is shown in Table 2 such that all those that vary together in one direction are shown by a + sign and those that vary together in the opposite direction by a — sign, and by grouping into two groups A and B.

TABLE 2

Test	Relationship	Group
F.S.C.	—	A
P.R.C.	+	B
P.F.C.	+	B
N.R.C.	—	A
N.F.C.	—	A
Dynamic	+	B
P.R.A.	—	A
N.R.A.	+	B
Bin. X Cyl.	+	B
Mon. X Cyl.	+	B

Thus F.S.C., N.R.C., N.F.C., and P.R.A. tend to vary either up or down together and P.R.C., P.F.C., Dynamic, N.R.A., Bin. X Cyl. and Mon. X Cyl. vary together and in an opposite direction from the first group.

These tests, having a tendency to vary together do not offer a single test for classification purposes. This single test (not the only test) that is not necessarily related to any other test is the gradient or accommodation-convergence ratio. The gradient has another advantage aside from being descrete in that its range of normal values is small, being only $\pm 1\triangle$. On the basis of this test subjects may be classified as to whether the relationship between accommodation and convergence is normal or

abnormal. If the finding is low then the amount of convergence associated with accommodation is low and this insufficiency must be made up by positive relative convergence stimulated either psychically by the subject being aware that the target is near or by fusion. On the other hand, if the finding is high, then there may or may not be overconvergence which must be overcome by negative relative convergence.

In the realm of accommodative cases there are two general types, one of fatigue and the other of insufficiency. The last type exhibits primarily a lowered amplitude of accommodation and therefore a lowered positive relative accommodation. In the accommodative fatigue type the tests in the A group of Table 2 will have a tendency to be low while those in the B group will have a tendency to be high. Not all tests in either group will vary in the proper way. This is to be expected since the relationships between these various tests are poor from the standpoint of predictability.

Conversely, in cases of convergence fatigue or insufficiency the tests in group A should be high and those in group B should be low. Again caution must be observed, since some of the tests will not be in the proper relationships.

In the calculating "lags" there have been many procedures advocated. The coefficient of correlation, however, between dynamic skiametry results and fusional supplementary convergence is extremely low, being only $+0.14 \pm 0.01$. Since the F.S.C. is being used to predict what dynamic skiametry should be, it is the square of the coefficient of correlation that is of interest. This is 0.0196 which multiplied by 100 to change into a percentage reading comes out to be 2%. Thus if the F.S.C. results are to be used to predict dynamic skiametry results, the accuracy would be only 2%. This accuracy is obviously too low to be considered. Thus using the technique of going to complete reversal of the reflex, with fixation and working distance coincident at 40 cms., and with the results compared to the subjective finding, if the dynamic finding is more than $+1.50$D greater than the subjective it is high and if it is less than $+1.25$D greater than the subjective it is low. In a similar way the coefficients of correlation between F.S.C. and the cross cylinder tests are too low to make any appreciable difference in accuracy whether the lags are taken from Table 1 or calculated on the basis of the F.S.C. and gradient.

On this basis it is also possible to deduce several types of syndromes which might be termed compensated types, but such deductions would

be stretching the data far beyond the limits of its reliability except for those subjects who have learned to supplement a poor positive relative convergence by the use of accommodative-convergence. Here there is a mixture of high and low findings in both groups A and B of Table 2.

This type of analysis allows one to classify subjects into types but it does not tell us what to do to alleviate the subject's complaint. In order to successfully prescribe the first requisite is a good case history. This is also the foundation of case analysis. What does the patient complain about? If the chief complaint, as a minimum requirement, is not alleviated, the optometrist has failed regardless of how fancy the classification, etc.

Since the gradient test is virtually independent of all other tests, it is possible, using it as a basis, to subdivide the accommodative fatigue and convergence cases into three separate divisions depending on whether or not the gradient is low, normal, or high. Now obviously in accommodative fatigue cases it is desirable to reduce the accommodative demand as much as possible. The question is how much can this be done without interfering too much with the accommodative-convergence reflex. Obviously, the key is the gradient finding but consideration must also be given to the other dynamic findings as well as the subjective finding. If the subjective finding has been determined properly, two things are known: First, the lenses that give maximum acuteness of vision and secondly, the amount of convex lens power that can be added binocularly to this without the subject experiencing blur—a fair 20/20 visual acuity on the average. Now those findings in group B of Table 2 will tend to be high and those in group A low if it is an accommodation case. The amount of additional convex lens power susceptible to measurement at close ranges can be determined by deducting the average "lags" from dynamic skiametry and the cross cylinder tests. The first question to settle is whether or not this amount is acceptable at near. This can be determined by considering the other tests. If, for example, P.R.C. is higher than N.R.C., F.S.C. is low and the gradient low, the maximum convex lens power possible will be acceptable at near since we know that the linkage between accommodation and convergence is low and this additional convex lens power will not interfere to any marked extent in the accommodative-convergence reflex. Whether or not this same lens is acceptable at distance can be inferred from the subjective since we have an idea of the subject's appreciation of blur. On the other hand if the gradient is high, the maximum may not be acceptable. Whether it is or not

depends upon the absolute values found in the tests of P.R.C., N.R.C., and F.S.C.

The procedure for prescribing for convergence cases follows the same line of reasoning. It is also possible to determine whether or not visual training should be given.

A great deal has been said in recent years about changing refractive states and even refractive errors by visual training. However, very little or nothing has been published of a scientific nature about such methods or the results obtained. Now it would obviously be advantageous if all refractive conditions were purely functional and subject to change by clinical methods. In view of this fact some 50 subjects over a period of several years have been given intensive training while some 50 others have been given training but not so intensive. These subjects were matched in groups as near as possible and different lines of approach to the problem were tried. A control group receiving no training was also set up. The methods used are too varied to be discussed in a paper such as this except to say that at least one group received every type of published technics that the writer could find from the palming and other methods advocated by Bates to the elaborate methods described in the O.E.P. monthly literature.

The findings that can be altered in order of ease in performing the alteration are shown in Table 3.

TABLE 3

1. Positive fusional convergence
2. Positive relative convergence
3. Adduction
4. Negative fusional convergence
5. Positive relative accommodation
6. Negative relative convergence
7. Abduction
8. Negative relative accommodation*
9. Additional convex lens power to perceptible blur at distance*
10. F. S. C.*
11. Phoria*
12. Amplitude of Accommodation*
13. Monocular X Cylinder*
14. Binocular X Cylinder*

No significant changes occurred in the findings listed in Table 4.

TABLE 4

1. Ophthalmometer
2. Static Skiametry
3. Subjective to best visual acuity
4. Dynamic Skiametry
5. Gradient

In some instances the amount of change in function was definitely limited. These are marked by the asterisk. For example, F.S.C. contains generally some convergence brought about by the stimulus of nearness. This amount could be varied to almost any amount ranging from 0 to 10 or more prism diopters, but the basic amount depending on accommodative-convergence was not altered permanently in a single instance. Likewise, in the case of the phoria a change of some $\pm 2\triangle$ could be made in tonus and in addition a certain amount of willed convergence could be temporarily associated with this. On the average a subject's tolerance of blur could be increased at least 0.50D.

It is interesting to note that no change occurred in the subjective for maximum V.A.

This method of case analysis is not necessarily the one taught in the School of Optometry of the University of California. The writer does not claim, either, that it is infallible.

It is a method of analysis that needs no exception for this or that type of case either myopia or hypermetropia. It is an attempt to find a method of case analysis based on scientific investigation.

A few case reports will illustrate the method of analysis.

CASE NO. 1

History: Frontal headaches that are more severe in the afternoon. Especially severe after reading or going to the movies. Symptoms have become more and more severe lately.

Subj. maximum V.A.	R.	+0.75 D.S.	V.A. 20/20
	L.	+0.50 D.S.	V.A. 20/20
20/20 O.U.	R.	+1.25 D.S.	
	L.	+1.00 D.S.	
Static skiametry	R.	+1.25 D.S.	
	L.	+1.00 D.S.	

Phoria-ortho—no hyperphoria

Adduction 10/20/9

Abduction 6/4

Dynamic Skiametry	R.	+2.25 D.S.
	L.	+2.00 D.S.
Mon. X Cly.	R.	+1.75 D.S.
	L.	+1.50 D.S.
Bin. X Cly.	R.	+1.25 D.S.
	L.	+1.00 D.S.

Fus. Sup. Conv. —4△; Gradient —4/+1.00

P.R.C. 17/20/10; N.R.C. 14/20/14

P.R.A. —2.25 D.; N.R.A. +2.00 D.

Amplitude R 10 L 10 O.U. 10

Patient's occupation is that of a typing and filing clerk.

Rx prescribed: R. +0.75 D.S., L +0.50 D.S.

Comments: All functions within normal limits. Therefore, a straight refraction case.

CASE NO. 2

History: Has had Rx for last several years. Present lenses are satisfactory, except for prolonged near work, after which the eyes become red and lids irritated.

Static Skiametry	R.	+1.00 ⌒ —0.50 axis 180°
	L.	+1.25 ⌒ —0.75 axis 180°
Subj. maximum V.A.	R.	+0.75 ⌒ —0.50 axis 10 °
	L.	+0.75 ⌒ —0.75 axis 170°
20/20 O.U.	R.	+1.50 ⌒ —0.50 axis 10 °
	L.	+1.50 ⌒ —0.75 axis 170°

Balance of tests through maximum visual acuity, subjective.

Phoria 1△ esophoria, no hyperphoria.

Adduction 9/25/16, Abduction 5/3.

Dynamic Skiametry	R.	+2.75 ⌒ —0.50 axis 10 °
	L.	+2.75 ⌒ —0.75 axis 170°
Mon. X Cyl.	R.	+2.25 ⌒ —0.50 axis 10 °
	L.	+2.25 ⌒ —0.75 axis 170°
Bin. X Cyl.	R.	+2.00 ⌒ —0.50 axis 10 °
	L.	+2.00 ⌒ —0.75 axis 170°

Fusional Sup. Conv. +1△, Gradient —4△/+1.00D.
P.R.C. 20/30/22, N.R.C. 6/15/7
P.R.A. —2.25 D.S. N.R.A. +2.75 D.S.
Amplitude R. 7.0 D. L. 7.0 D., O.U. 7.0 D.

Old Rx.	R.	+0.75	—0.50	axis 180°
	L.	+0.75	—0.75	axis 180°

Comments: It will be noted that the group A tests tend to be low while the group B tests tend to be high. The relationship between accommodation and convergence is normal. Deducting arbitrary "lags" we find:

Dynamic Skiametry	R.	+1.25 ⌒	—0.50	axis 10 °
	L.	+1.25 ⌒	—0.75	axis 170°
Mon. X Cly.	R.	+1.25 ⌒	—0.50	axis 10 °
	L.	+1.25 ⌒	—0.75	axis 170°
Bin. X Cly.	R.	+1.50 ⌒	—0.50	axis 10 °
	L.	+1.50 ⌒	—0.75	axis 170°
Rx. given for constant wear	R.	+1.25 ⌒	—0.50	axis 10 °
	L.	+1.25 ⌒	—0.75	axis 170°

Complete alleviation of symptoms within a few days.

CASE NO. 3

Patient: Complains that he falls asleep after reading only a short time. Very few headaches. Been wearing "strong" lenses for some time. During his "teens" lenses were changed about once a year, stronger each time. Has had present lenses four years. Occupation: lawyer, age 31 years.

Visual Acuity old Rx., R. 20/20, L. 20/20, O.U. 20/20
Visual Acuity no Rx., R. 20/400, L. 20/800, O.U. 20/400

Static Skiametry	R.	—4.25 ⌒	—0.75	axis 180°
	L.	—5.75 ⌒	—1.25	axis 180°
Subjective, Max. V.A.	R.	—4.50 ⌒	—0.50	axis 5 °
	L.	—5.75 ⌒	—1.25	axis 175°
20/20 O.U.	R.	—4.00 ⌒	—0.50	axis 5 °
	L.	—5.25 ⌒	—1.25	axis 175°

Phoria 2△ esophoria, No hyperphoria
Fus. Sup. Conv. —8△, Gradient —1/+1.00
P.R.C. X/10/4 N.R.C. X/25/18
Adduction X/15/5 Abduction 8/4

Dynamic Skiam.	R.	—3.00 ⌒	—0.50	axis 5 °
	L.	—5.25 ⌒	—1.25	axis 175°
Mon. X Cyl.	R.	—3.50 ⌒	—0.50	axis 5 °
	L.	—4.75 ⌒	—0.50	axis 175°
Bin. X Cyl.	R.	—4.00 ⌒	—0.50	axis 5 °
	L.	—5.25 ⌒	—1.25	axis 175°

Amplitude R. 11.0 D., L. 11.0 D.

Comments: Nearly all the findings are in the normal range. There is an abnormal relationship between accommodation and convergence such that relative convergence must make up for a serious lack in accommodative-convergence. This was made evident also in making the measurements in that when the first attempt was made to measure fusional supplementary convergence the result was +2△, but as the target was moved back and forth by means of the Risely prism it gradually changed and settled down to —8△.

Orthoptics was given to build up P.R.C. After twelve visits this was brought up to X/35/20. In six months without orthoptics it dropped to X/28/18. The lenses were not changed. The patient reports complete comfort.

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THE EFFECTS OF BASE-IN AND BASE-OUT PRISMS ON STEREO-ACUITY *

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INTRODUCTION

The present investigation was undertaken to find the explanation for the loss in stereo-acuity which occurs when the stimulus to accommodation is kept constant and changes in convergence are induced by means of base-in and base-out prisms.

Our attention was called to this phenomenon in 1937 by Dr. J. L. Barnes, an optometrist of Fostoria, Ohio, who was proposing that loss in stereopsis be used as a criterion of the limit of tolerance of base-in and base-out prisms. Since some subjects show no appreciable loss in stereo-acuity with base-in and base-out prisms up to the point at which diplopia sets in, the basic idea is not universally applicable, but a study of these phenomena contributes to our understanding of the factors influencing stereo-judgments.

The investigations described in this report were carried out during the period from the Winter of 1937 through the Summer of 1939.

APPARATUS

One form of apparatus used for measuring stereo-acuity is illustrated in Fig. 1. R is a screen with a rectangular aperture. Y represents a

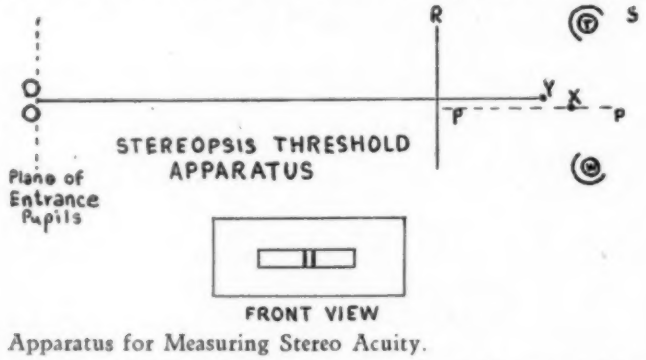

Fig. 1. Apparatus for Measuring Stereo Acuity.

vertical black rod ¼" in diameter, whose position was fixed 6 meters from the pupillary plane. X is a second vertical black bar ¼" in diam-

* Submitted on October 23, 1944, for publication in the December, 1944, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

eter which moved along the path pp' 1 inch to the right of Y. Its movement was controlled by strings operated by the subject. The pegs were seen through an aperture in the black screen at R and against the white background provided by the screen at S which was illuminated by the lamps T and W. The appearance of the two bars through the aperture is shown in the lower part of the figure.

The base-in and base-out prisms were provided in the form of a pair of rotary prisms attached to a phorometer trial frame, which was adjustable for the subject's inter-pupillary distance. The phorometer trial frame was mounted to a stand which was kept in a fixed position. The openings for the two eyes were kept at the same level as the center of the aperture in screen R.

The first step in the experiment was to determine the maximum amount of base-in prism that could be tolerated. This was determined by increasing the power simultaneously for the two eyes until the image doubled and then the power was reduced until fusion was recovered. The power was further reduced until the total power of the two prisms represented an even number of prism diopters and this represented the first prism power with which settings were made.

The rod (X) was set in the same frontal plane as Y and the subject was instructed to pull X forward until it appeared to be in front of Y. The position of X was then recorded and the subject was required to use a second string to pull X backward until it appeared behind Y. This second setting was also recorded and this whole procedure was repeated two more times. Averages were computed for the two limits of the zone in which X and Y appeared to be in the same plane. The range between these two limits was then divided by two and the result was regarded as a measure of the minimum perceptible difference in distance.

The prism power was then reduced 1△ for each eye, making a total reduction of 2△ and the whole procedure was repeated. Subsequently, the prism power was changed in steps of 2△ in the direction of less base-in or more base-out until the subject was no longer able to maintain fusion, or until his stereo acuity became so poor that the instrument was not adequate for measuring it. In no case was the experiment carried beyond 20△ base-out, although some of the subjects showed no impairment either of stereo acuity or ability to fuse.

TYPICAL RESULTS OBTAINED WITH BASE-IN AND BASE-OUT PRISMS

Typical results obtained in this experiment are illustrated in Fig. 2 and Fig. 3. In Fig. 2, none of the subjects are affected by base-in but

all of them are markedly affected by base-out. In Fig. 3, two of the subjects show an impairment of stereopsis, both with base-in and base-out

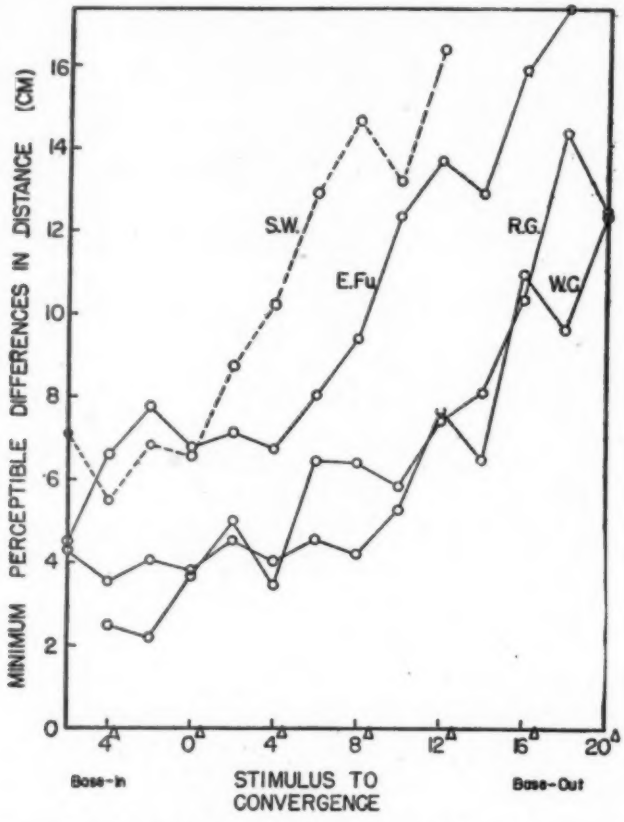

Fig. 2. Data for Four Subjects Showing the Relation of Stereo Acuity to Base-In and Base-Out Prisms.

and two of them show no appreciable effect with either base-in or base-out. The subjects were seniors in the School of Optometry except in the one case of an instructor. Glasses were worn during the experiment if they were normally used for distance vision.

THE ROLE PLAYED BY BLURREDNESS OF THE RETINAL IMAGE

It is a well-known fact that certain subjects will not only respond to base-out prisms by increasing convergence, but will eventually permit accommodation also to come into play. Other subjects maintain a clear image until base-out prism is increased to the point that fusion gives way. This might account for the fact that some subjects showed an impairment of stereopsis with base-out prism while others showed no ap-

preciable effect, but it could not account for the impairment of stereopsis with base-in prisms in the cases of G. F. and E. F., because at 6 meters

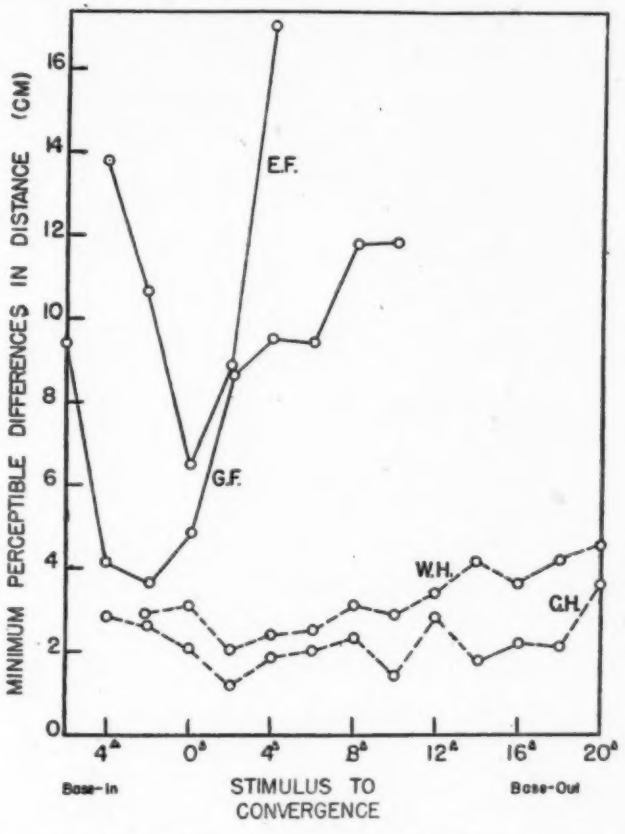

Fig. 3. Data for Four Subjects Showing the Relation of Stereo Acuity to Base-In and Base-Out Prisms.

accommodation is at its zero level and no further relaxation occurs under the influence of base-in prism. Relaxation might occur in the case of an uncorrected or under-corrected hyperope or in the case of an over-corrected myope and make the image more blurred, but both G. F. and E. F. were slightly under-corrected myopes and hence if accommodation had relaxed, the image would have become sharper instead of more blurred.

In order to demonstrate the impairment in stereo acuity that can be produced by throwing the eyes out of focus, the following experiment was designed. The apparatus used is illustrated in Fig. 4. This is essentially the same apparatus as illustrated in Fig. 1 with the exception that the screen S consisted of a piece of milk glass which was illuminated

from the rear and screen R was illuminated by diffuse reflection with lamps placed at such a distance that the screen appeared to have the same

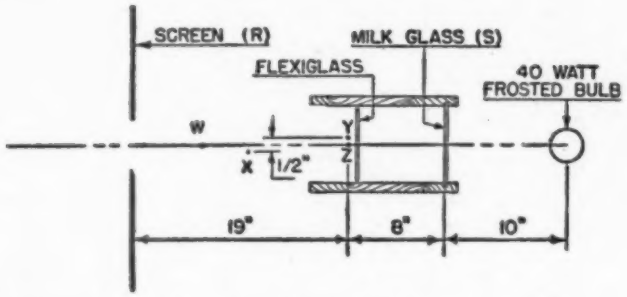

Fig. 4. Apparatus for Measuring Stereo Acuity.

brightness as the milk glass seen through the aperture. The aperture in the screen was a square four inches on each side. One type of target (Fig. 5C) used with this apparatus consisted of a black annulus painted on the front of the milk glass and a small black disc painted on the back of a piece of flexiglass which was parallel to the plane of the milk glass and moved in an antero-posterior direction. The base to which the flexiglass is attached was operated by a chain drive and reversible motor.

Push button switches were connected in parallel for the subject and experimenter. The speed of the motor was controlled by rheostat and was kept constant with the flexiglass moving at a rate of 2 cm. a second. At this rate the flexiglass moved about 5 mm. after the subject released the switch. In order to make a setting, the back of the flexiglass was placed in contact with the front of the milk glass. The subject pressed his push button switch to start the motor and the flexiglass moved forward. When the disc appeared to be in front of the annulus the subject released his switch to stop the motor. The operator then recorded the position of the flexiglass, threw the reversing switch and turned on the motor to bring the flexiglass back to the plane of the milk glass. The motor was then turned off and the reversing switch thrown; and the subject was required to repeat the operation. Five such repetitions were required for each set of conditions, the average distance of the disc in front of the annulus being taken as a measure of the minimum perceptible difference in distance.

The stimulus pattern illustrated in Fig. 5B was obtained by using a plain piece of milk glass at S and suspending a ¼ inch vertical rod at

Y and substituting for the flexiglass a second ¼ inch vertical rod (X) which moved in an antero-posterior direction along a path 1 inch to the right of Y. Although this arrangement permitted the rod (X) to move past the rod (Y) in both directions, the procedure used was the same as with the disc and annulus, namely, the movable rod was first placed in the plane of the fixed rod and then moved forward until it appeared just in front.

The stimulus pattern in Fig. 5A was obtained in the same way as

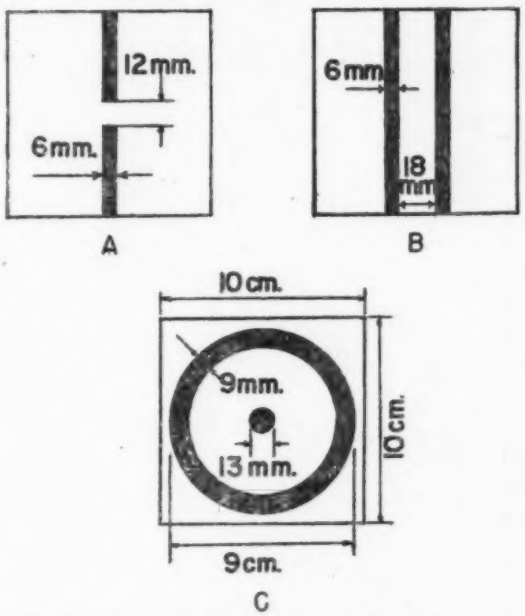

Fig. 5. Targets Provided for the Apparatus in Fig. 4.

that in Fig. 5B except that the rods were both located on the center line and the fixed rod (Z) extended downward only part of the way across the aperture and the movable rod (W) was cut off so that its top fell 12 mm. below the bottom of the fixed rod (Y).

The observer was seated in front of the phorometer trial frame which was so adjusted that when the forehead was in contact with the forehead rest, the pupillary plane lay approximately 6 meters from the plane of the fixed target. The phorometer trial frame was provided not only with rotary prisms but also with cells for holding trial lenses.

In the particular experiment under discussion, stereopsis was measured with different amounts of + and — lenses starting with —.50 D. added to the distance correction and going in steps of .25 D. in the direction of less minus or more plus, until stereopsis was impaired to the point

that it could not be measured with the apparatus. Inasmuch as the experiment was performed to determine the effect of different degrees of blurredness on stereopsis an attempt was made to measure visual acuity through each pair of lenses with a Snellen chart placed in contact with screen R.

In Fig. 6 the data for two subjects are presented showing the relationship between the minimum perceptible difference in distance and

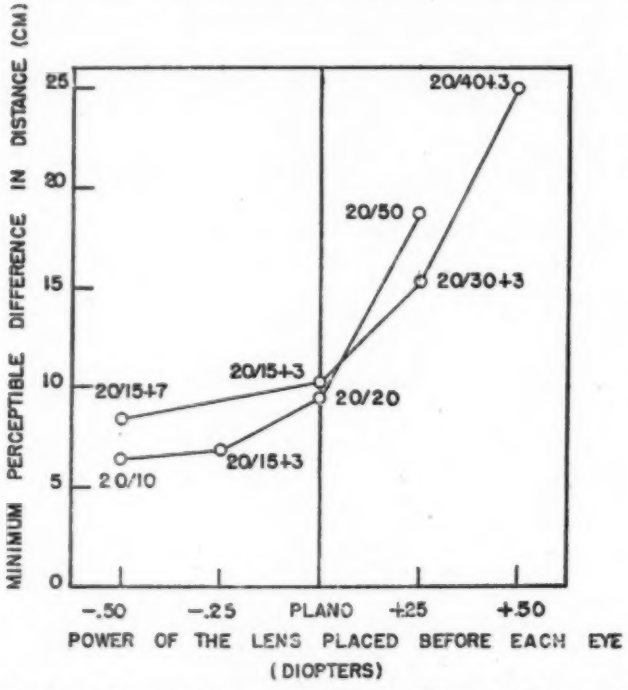

Fig. 6. Data for Two Subjects Showing the Effects of Plus and Minus Lenses on Stereo-Acuity. The Visual Acuity at each Point is Indicated.

the amount of lens power added to the distance correction. At each point on the graph the visual acuity is indicated. There can be no question in this type of experiment that the impairment of stereopsis is directly associated with the increase in blurredness.

In order to measure the degree of blurredness more effectively, the apparatus was revised as illustrated in Fig. 7. A piece of ground glass (S) was substituted for the milk glass and this was illuminated from behind by two small bulbs. The ground glass was not uniformly illuminated but nearly enough so to obtain the type of data wanted. A lamp was placed at the proper distance in front of the screen (R) to make it

appear equally bright as the ground glass seen through the aperture. The rods were arranged to make the stimulus pattern conform to that shown

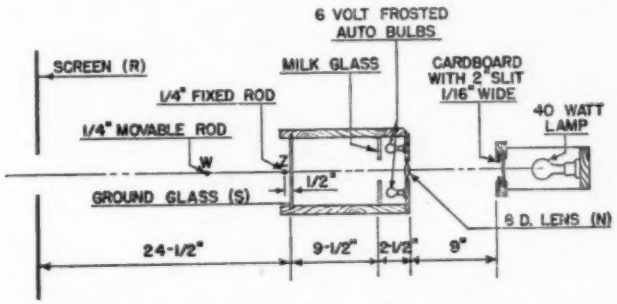

Fig. 7. Modification of the Apparatus in Fig. 4 to Provide for the Measurement of the Blurredness of the Retinal Image.

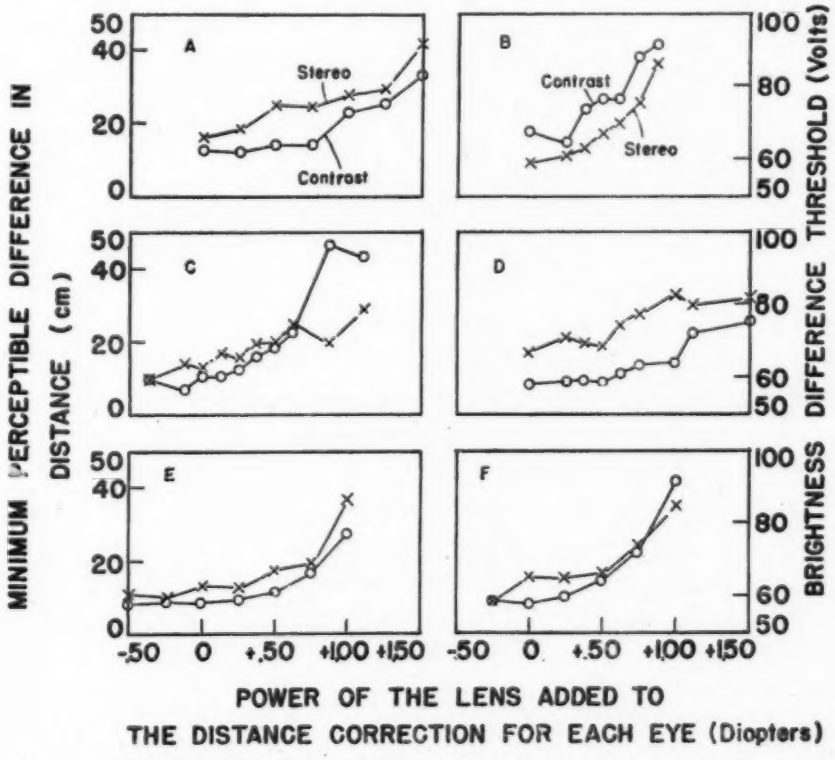

Fig. 8. Data for Six Subjects Showing the Relation of the Stereo and the Contrast Threshold to Various Plus and Minus Lenses.

in Fig. 5A. A sheet of black cardboard with a horizontal slit was placed

at M with a piece of ground glass behind it. The ground glass was illuminated from the rear by a 40 watt bulb whose voltage was controlled with a variac. The lens at N focused an image of the horizontal slit on the ground glass (S). When this slit image was bright enough it could be seen by the observer and the voltage could be regulated by the observer to determine the contrast threshold.

The intensity threshold increases as the blurredness of the retinal image increases because the light is scattered over a larger area and the intensity at the center is cut down. This loss has to be compensated by increasing the voltage. The threshold measurements have been expressed in terms of voltage. Although it is possible to use threshold measurements of this sort to determine quantitatively the degree of blurredness, no attempt has been made to do this in the present experiment.

In carrying out an experiment with this apparatus, essentially the same procedure was used as with the apparatus in its original form. During the stereo-settings the brightness of the slit image was kept below the threshold level and after each setting the subject increased the voltage until the horizontal slit became visible. The voltage as well as the position of the movable rod was recorded.

Stereo and contrast threshold measurements were obtained for a number of subjects whose data are presented in the graphs in Fig. 8. For all the subjects the loss in stereopsis is always correlated with an increase in the contrast threshold.

LOSS IN STEREO-ACUITY THAT IS NOT DEPENDENT ON INADEQUATE FOCUS

It has already been pointed out in connection with Fig. 3 that the impairment of stereopsis with base-in prisms which occurs in the case of subjects E. F. and G. F. cannot be accounted for by inadequate focus.

The following experiment provides another demonstration that over or under accommodation is not a necessary adjunct to convergence in reducing stereo-acuity. The experiment was carried out with the stimulus pattern in Fig. 5A and the apparatus in Fig. 7. Measurements of stereo acuity were made in the usual manner with various amounts of minus lenses added to the distance correction of the subject. The results are shown in Fig. 9. Subject A in Fig. 8 served also in this experiment. The fact that the subject was able to accommodate to maintain a clear image is proved by the fact that the threshold for the horizontal line remains practically constant during the entire experiment. The impairment in stereo acuity cannot depend upon poor focus. One factor

that needs to be considered is the relationship between accommodation and convergence. Accommodation forces convergence into play and this

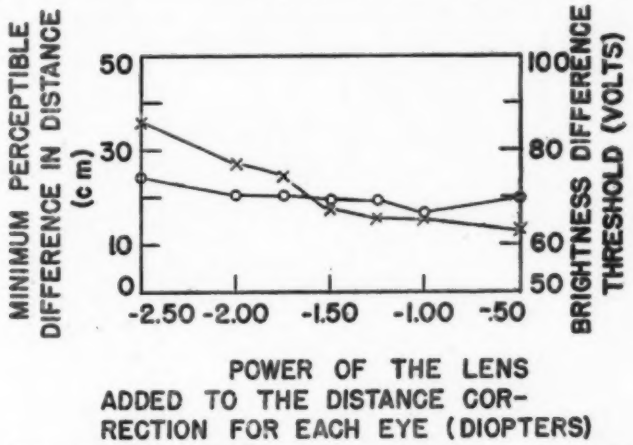

Fig. 9. Data for Subject A Showing the Relation of Stereo Acuity and the Contrast Threshold to Minus Lenses.

has to be compensated by a negative type of convergence which can be identified with the negative fusional convergence that is necessary to compensate base-in prisms at 6 meters. In a sense, therefore, the effect obtained with minus lenses shown in Fig. 9 is related to the effect obtained with base-in prisms at 6 M (see G. F. and E. F. in Fig. 3).

THE ROLE OF FIXATION DISPARITY

One factor which might impair stereopsis without throwing the eyes out of focus is fixation disparity. It is conceivable, for example, that when base-in prisms are used, the eyes are not able to diverge enough to keep the images on corresponding parts of the two retinas and consequently in the case of the target in Fig. 5B there might be some tendency for the dextrocular image of X to fuse with the sinistrocular image of Y as shown in Fig. 10. This factor, however, is ruled out in the use

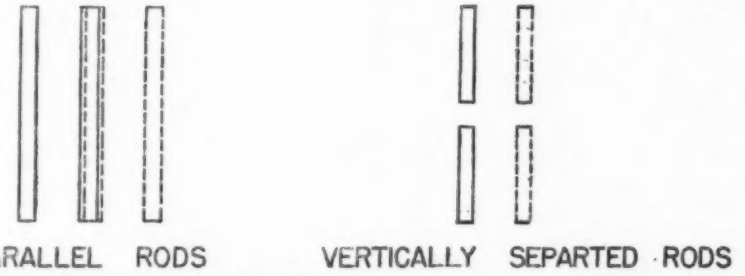

Fig. 10. Effect of Eso-Fixation Disparity on the Fusion of Parallel and Vertically Separated Rods.

of the stimulus pattern illustrated in Fig. 5A in which the dextrocular image of one rod can not be confused with the sinistrocular image of the

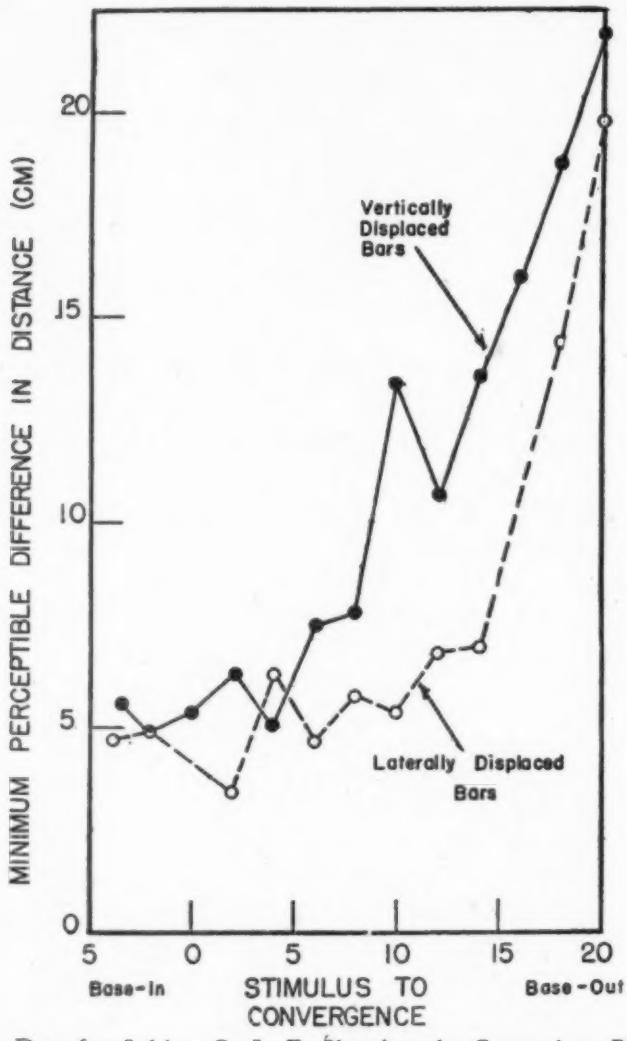

Fig. 11. Data for Subject G. A. F. Showing the Comparison Between Effects Obtained with Parallel and with Vertically Displaced Bars.

other rod, but essentially the same results are obtained with this type of pattern as with a pair of parallel rods. Fig. 11 shows a comparison of the data for the same subject with the two types of patterns. Furthermore, none of the subjects reported an actual change from two bars to a three-bar effect with the parallel bar target in Fig. 5A. Under strong

prisms, however, fusion does become unstable and the images alternate between fusion and slight amounts of diplopia.

THE ROLE OF CHROMATIC DISPERSION OF THE PRISMS

In order to determine the possible role that might be played by the chromatic dispersion of the prisms, an attempt was made to compute the extent to which it blurs an image. The maximum prism power used before each eye was 10△. This produces a total effect of 20△. The problem is illustrated in Fig. 12 which shows the effect of differential

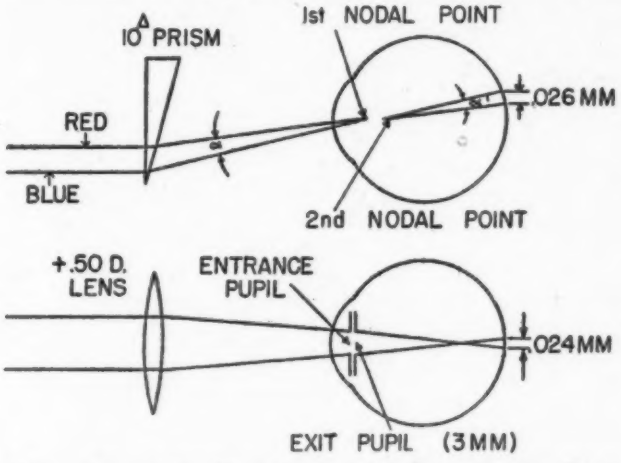

Fig. 12. Comparison of the Blurredness of the Retinal Image Produced by Chromatic Dispersion with a 10△ Prism and that Produced by Throwing the Eye out of Focus with a +.50 D. Lens.

prismatic displacements for different wave lengths of light. Red rays and blue rays from the same distant point source arrive at the first nodal point from different directions, and therefore, the images on the retina will be separated. The amount of separation can be calculated since the partial dispersion for the C and F lines of the spectrum for ophthalmic glass is .00895. The angle, X, represents the angular dispersion for the C and F lines of the spectrum and is calculated for a 10△ prism to be .092°. Since X′ is equal to X and since the distance from the second nodal point to the retina is 15 mm., the actual separation between the red and blue images is .026 mm.

If we assume that a +.50 D. lens will form an image .167 mm. in front of the retina and that the exit pupil has a diameter of 3 mm. and lies 18.66 mm. in front of the retina, the blur circle for a point image would have a diameter of .026 mm.

In comparing the blurredness produced by a prism with that pro-

duced by a lens, it is necessary to consider the fact that light is more or less uniformly distributed in the blur circle produced by the lens, whereas the image produced by the prism is equivalent to a spectrum. The distribution of the light in the spectrum depends upon the energy distribution of the 40 watt bulb used to illuminate the milk glass and the visibility curve of the observer. The energy distribution of the source was assumed to be equivalent to that of a black body at 2700° K. The luminosity curve shown in Fig. 13 was calculated by multiplying the

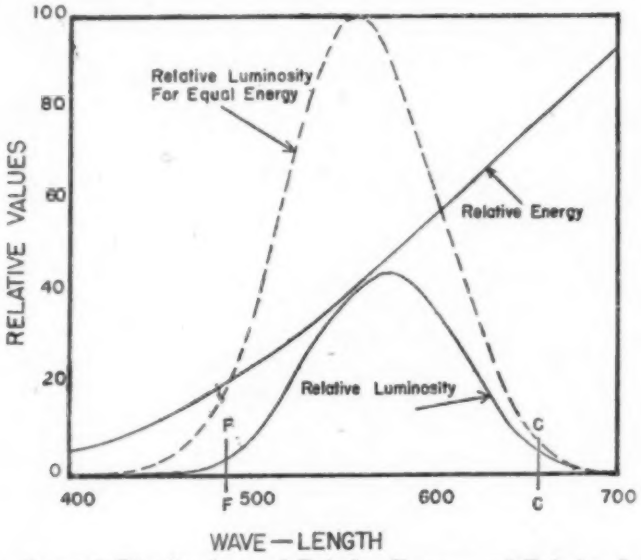

Fig. 13. Spectral Distributions of Relative Energy and Relative Luminosity for a 40 Watt Lamp. The dotted curve represents relative visibility for a "standard observer."

values for relative energy by the relative visibility values for a "standard observer."[1]

It may be concluded, therefore, that a 10△ prism will produce approximately the amount of blur through chromatic dispersion than throwing the eyes out of focus to the extent of .50 D. According to the data shown in Figs. 6 and 8, this amount of blur should be effective in reducing stereopsis, at least to a slight extent.

Another method of demonstrating the effect of chromatic dispersion consists in carrying out the experiment with prisms placed base-in over the right eye and base-out over the left eye. In Fig. 14 is shown a comparison of the data obtained for one subject with prisms placed with their bases opposite and with their bases in the same direction. The data

[1]L. T. Troland, the Principles of Psychophysiology, Vol. III, 69, 70 (1930).

were obtained with the apparatus illustrated in Fig. 4 and the stimulus pattern illustrated in Fig. 5B. The effect with prisms with bases in op-

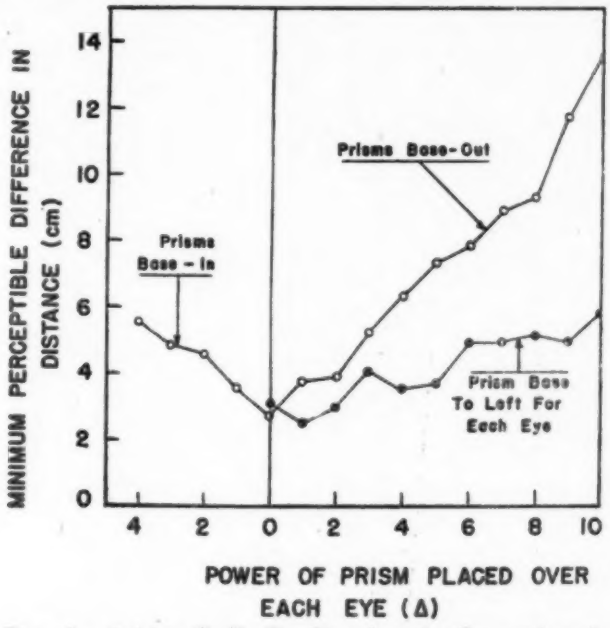

Fig. 14. Data for Subject P. R. K., Showing the Comparison between the Effects Obtained with Prisms with Bases in the Same and in Opposite Directions.

posite directions is much greater than with bases in the same direction, and the effects obtained with base-in and base-out prisms can be only partially attributed to the chromatic dispersion of the prisms.

It would be possible to eliminate the effects of the chromatic dispersion of the prisms by using a variable mirror arrangement to substitute for the prisms or by using prisms which are corrected for chromatic dispersion; or by using filters or light sources that are relatively monochromatic.

EFFECTS OF FATIGUE

One important discovery that was made during the course of the experiments consisted in finding that if the experiment with prisms is done in the reverse order, that is from base-out to base-in, markedly different results are obtained than when the prisms are taken in the usual order from base-in to base-out. Fig. 15 shows a comparison of the data obtained with the prisms used in the two orders, that is from base-in to base-out and from base-out to base-in. The data were obtained with the apparatus in Fig. 4 and the stimulus pattern in Fig. 5B. This type of experiment serves to illustrate that fatigue effects are quite important.

The marked impairment in stereopsis which occurs with base-in prisms when the reversed order is used, cannot be attributed to an increase in blurredness because the rods remained perfectly clear. It should be noted further that with the reversed order the maximum tolerance for base-in is less than with the usual order. This indicates that a temporary tendency toward esophoria is produced by the use of prisms base-out.

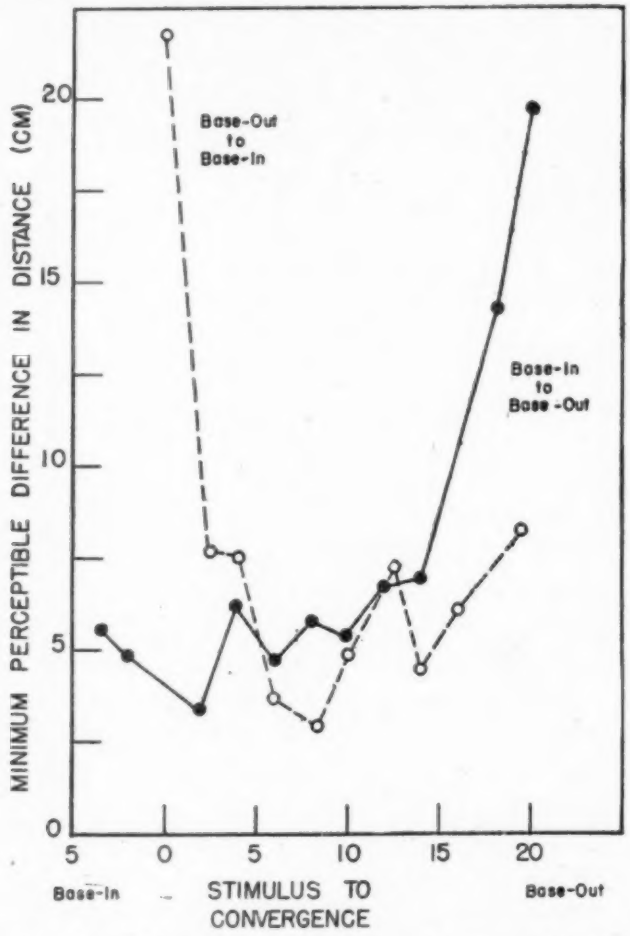

Fig. 15. Data for Subject G. A. F., Showing the Comparison between the Effects Obtained with Prisms Used in Opposite Orders.

CONCLUSIONS

The experiments reported in the present paper have served to demonstrate that both base-in and base-out prisms may impair stereo acuity in some cases. In other cases base-out prisms produce the effect whereas

base-in prisms fail to produce any measurable change. In still other cases no effects are obtained with either base-in or base-out.

The effects produced by prisms can be attributed only in part to chromatic dispersion because the blurredness produced by dispersion with the strongest prism used is not more than would be produced by throwing the eyes out of focus to the extent of .25 to .50 D. Furthermore, using prisms with their bases in the same direction fail to produce as much effect as using prisms with their bases in the opposite directions.

An important factor in the effect obtained with base-out prisms is that convergence calls into play accommodation which throws the eyes out of focus and this in turn impairs stereo acuity.

Improper focus of the eyes is not the only factor involved because base-in prisms and minus lenses also impair stereopsis without throwing the eyes out of focus.

The fact that throwing the eyes out of focus will impair stereopsis can be demonstrated by measuring stereopsis at 6 meters with plus lenses added to the distance correction. In experiments of this type attempts have been made to measure both the blurredness of the retinal image and the stereo acuity.

Fixation disparity may play an important role, but the amount of it present during the various stages of the experiment has not been measured and its relative importance has not been determined. In order to determine whether lateral fixation disparity introduces confusion when a pair of parallel vertical bars is used, vertically displaced bars were used as a substitute, but there was no essential difference in the results.

In event that the effects on stereo acuity obtained with prisms cannot be explained in terms of the effects of the intraocular and extraocular muscles on the clarity and placement of the optical images on the retinas, there is still the possibility that convergence in some way influences the interpretation of the retinal impressions after they reach the cortex.

The usual procedure in these experiments has been to take the prisms in the order from base-in to base-out. Using the prisms in reverse order demonstrates that fatigue effects play an important role. The manner in which fatigue operates has not been determined.

RECONDITIONING THE COLOR-BLIND. A CASE REPORT*

Israel Dvorine, Opt.D., F.A.A.O.
Baltimore, Md.

Although the writer is convinced that the term "color-blind" is a misnomer and should not be applied to every individual who fails to pass a color perception or color discrimination test, nevertheless, in view of the general acceptance of this term and in the absence of a more appropriate one, he will continue to use it in order to avoid confusion.

The following is a case report of a young man, H. C. E., age 17, who attempted to enlist in the army air corps three months ago and was rejected for color-blindness. He also made an effort to join the marine corps but was rejected for the same reason. On October 4 of this year, 11 days before his 18th birthday, he was accepted by the writer for training in color discrimination.

HISTORY

The patient claimed that prior to taking the army air corps test he had no idea that he was color-blind and that during his school years he had no difficulty in matching colors except that he would occasionally call a color by the wrong name. A year ago his brother tried to join the navy but was rejected for color-blindness and since then the patient had been worried that he too may be color-blind and not know it. His rejection by the air corps convinced him that his condition must be an inherited family trait and he resigned himself to this situation until he heard about the training being given to the color-blind. His father and mother, he said, have perfect color perception.

EXAMINATION

The ophthalmoscopic examination disclosed a normal fundus with a sharply outlined disk. He was not refracted but his visual acuity was taken and it was found to be 20/20 in each eye and the amplitude of accommodation was normal for his age. The tests for color perception and color discrimination included the A. O. Pseudo-Isochromatic Charts, the Ishihara Charts, the Dvorine Color Perception Testing Charts and the Holmgren Wool test. The results were as follows:

A.O., Pseudo-Isochromatic Charts—Patient failed 27 out of 46 charts.
Ishihara Charts —Patient failed 14 out of 32 charts.

* Submitted on October 17, 1944, for publication in the December, 1944, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

Dvorine Charts —Patient failed 15 out of 60 charts.
Holmgren—Confused red with violet, blue with violet and green with gray.

According to the foreign tests he was classified as a red-green blind. The Dvorine Color Perception Testing Charts disclosed that he was "Type 4," that is, his nomenclature for colors was incorrect and his color discrimination was defective for the following color combinations: red and green, red and brown, red and gray, yellow and orange, yellow and green, yellow and brown, blue and violet, orange and green, orange and brown, and brown and green. He was accepted for training with the understanding that he might not improve sufficiently in time to pass the army air corps test before his 18th birthday.

TRAINING PROCEDURE

The training in color discrimination was begun on October 6 and each session lasted a half an hour, once a day, until October 13, when he was given three training sessions in one day. The material used for training consisted only of the Dvorine Color Perception Testing and Training Charts. Volume one of this set, the testing charts, were not used for training until October 11.

During the first session it was explained to him that the three primary colors are red, yellow and blue and that the secondary colors, obtained by mixing two primary colors, are orange, green and violet; that gray is a mixture of black and white and brown is a mixture of all three primary colors. The first four pages of the training volume, consisting of 96 circles of dark and light tints of the eight basic colors, were then exposed and he was asked to name each colored circle. He made several errors, especially in discriminating between green and gray and blue and violet. He was under the impression that there are many colors whose names he did not know and he was relieved to learn that the recognition of the eight basic colors, red, yellow, blue, orange, green, violet, brown and gray, is sufficient for a working knowledge of colors. It was explained to him that it is not necessary to call light orange "salmon" or "peach" or to call violet "lavender." He was advised to prefix the word "light" to any light color in order to avoid confusion of names and the learning of new ones, for the time being. Thus, in naming the very light tints on page four of the DVORINE COLOR PERCEPTION TRAINING CHARTS, he was instructed to call them: light blue, light yellow, light green, light brown, etc.

The next visit was devoted to a review of the previous training

session and to a study of some of the charts in the training volume. The charts with the green-orange and blue-violet color combinations confused him more than the others in the book. He was given a dry, thin, artist's paint brush and he was directed to outline the numbers on the charts. If a number appeared to fade out while he was dry painting it, he was told to close his eyes and to reopen them after a few seconds, each time upon reopening his eyes to count the number of seconds that he was able to retain visibility of the number before it faded out again. Thus the training proceeded for the next few days until October 10, when he was again retested with the same testing material that was used when he was examined for the first time. The following was the result:

A. O. Pseudo-Isochromatic Charts	—Patient failed 5 out of 46 charts
Ishihara Charts	—Patient failed 3 out of 32 charts
Dvorine Charts	—Could see all of the 60 charts
Holmgren	—No confusion of colors

The training sessions were resumed. This time both volumes of the Dvorine Color Perception Testing and Training Charts were used daily until October 14, when he was again retested with the foreign sets. This time he named all the numbers correctly but was a little slow in his recognition of charts No. 27, 29 and 44 of the A. O. set, and the No. 9 of the Ishihara, which appeared to him at first as 54 instead of 74.

In view of the fact that this was the last day before his 18th birthday and the last day for enlistment in the air corps, he was advised to try at once to enlist. Although he was previously rejected for failing to pass the color perception test, this time he passed the test and was accepted by the air corps.

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AMERICAN JOURNAL OF OPTOMETRY
and ARCHIVES *of*
AMERICAN ACADEMY OF OPTOMETRY

Established 1924

Vol. 21 DECEMBER, 1944 No. 12

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Publication Office: 1501-04 Foshay Tower, 821 Marquette Av., Minneapolis 2, Minn.
Academy Office: 901-903 Lexington Building, Baltimore Maryland.

Annual Subscription, $4.00 in Advance; Canada, $4.50; Foreign, $5.00;
Single Copies, 50c.

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Published Monthly by the
AMERICAN JOURNAL OF OPTOMETRY PUBLISHING ASSOCIATION

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THE MEDICAL TREATMENT OF GLAUCOMA*

A large proportion of all patients with glaucoma require medical treatment. In cases of acute glaucoma a brief trial of medical control is indicated before surgery. In chronic types the tension may be kept within normal limits by medical treatment alone for long periods of time—often indefinitely. Therefore it is profitable for us to consider carefully the means by which this control may be maintained.

* An abridgment of the material presented to the optometrists of Minnesota by the Minnesota Society for the Prevention of Blindness, 503 Hamm Building, St. Paul, Minn. Submitted for publication, as part of a "Control of Glaucoma" program, on February 15, 1944.

In the majority of cases of glaucoma, especially the chronic type, the abnormally high intra-ocular tension may be assumed to result from some blockage of the filtration angle of the anterior chamber, where the aqueous, formed at the surface of the ciliary body, is drained away into Schlemms canal and thence into the general venous circulation. In a few cases, and more commonly in acute glaucoma, the drainage may not be too bad, but more than a normal amount of aqueous is being formed at the ciliary body. Blockage of the filtration angle is caused by two mechanisms. First, the meshwork of fibers which covers the opening into Schlemms canal may be blocked by inflammatory exudates, as in iritis, or by cellular debris, especially cells sloughed off by the pigment epithelium of the iris. Secondly, the blockage of the angle may be by the root of the iris, which either moves forward from its normal position or is thicker than it should be. We know that even if the filtration angle is partially blocked by cellular debris the escape of the aqueous may be adequate until the iris interferes somewhat also.

This description of some of the basic causes of increase in the intra-ocular tension leads us logically to the mechanisms by which we may hope to control the tension medically. Obviously we have no medicine which will dissolve away any cells which may be lodged in the meshwork of fibers forming the filtration angle, although in the case of inflammatory exudates they may melt away with the conclusion of the inflammatory process. We can, however, do something to control the position and thickness of the root of the iris. When the pupil is dilated the root of the iris becomes thicker and thus tends to block the angle. Conversely when the pupil is contracted the root of the iris is stretched thinner and the filtration angle is freed of that much obstruction. Therefore the medicines used locally in the eye for the control of glaucoma are miotics, which forcibly contract the pupil. Of such drugs the more commonly used are pilocarpine and eserine, and more recently prostigmine. A 1% solution of pilocarpine (hydrobromide), one drop instilled in the eye three times a day, is a moderately strong miotic, which may suffice in a case of chronic glaucoma which is not too severe. A 2% or 5% solution is correspondingly more powerful, and use at more frequent intervals may be necessary, but a solution as strong as 5% may be irritating to the conjunctiva if used over a long period. Prostigmine (5% solution) is about comparable to pilocarpine in its action, but may be effective and tolerable when pilocarpine is not. Eserine 1/5% is about comparable in strength to a 1% or 2% pilocarpine solution, and eserine solutions which may be used up to 1% or 2% are much more powerful,

but also much more irritating, and can rarely be used for routine treatment over any length of time. Eserine, and perhaps to a lesser extent pilocarpine also, has another action besides the contraction of the pupil, in that it inhibits to some extent the formation of aqueous at the ciliary body. This aids in bringing the tension to normal, reinforcing the miotic action which improves the drainage of aqueous out of the eye.

In acute glaucoma nothing less than 1% eserine is likely to be effective, and even that may be insufficient. In acute glaucoma other drugs and systemic treatment such as dehydration with hypertonic solutions of sugars may be used also. Every patient with acute glaucoma should be hospitalized at once while such measures are tried, and surgery should not be delayed if they are not effective within the first 24 hours.

A newly diagnosed case of glaucoma must be observed frequently during the early stages of medical treatment to establish the strength and frequency of dosage which will be sufficient to maintain normal intra-ocular tension. In an average case, where the original tension was not too terribly high and the visual fields not too badly impaired, it may be sufficient to measure the tension every few days to a week, with the intervals increasing as control is established to 2, 3, or even 4 months. The visual fields should be carefully mapped on a perimeter and tangent screen at least every month or two to begin with and never less than two or three times a year. In some cases the changes in the visual fields are a more sensitive indication of the status of the case than the intra-ocular tension, since a few cases will lose ground steadily even though the tension as measured with a tonometer is apparently well within normal limits. The patient's vision is never a safe criterion, since the central vision may be good until the visual fields are extremely contracted and complete blindness is only a short step away.

PUBLISHERS' NOTICE—The annual meeting of the AMERICAN ACADEMY OF OPTOMETRY is being held in Chicago, December 10, 11, and 12 at the time the December, 1944, issue of this publication is coming off the press. Our January, 1945, issue will carry a complete report of this meeting.

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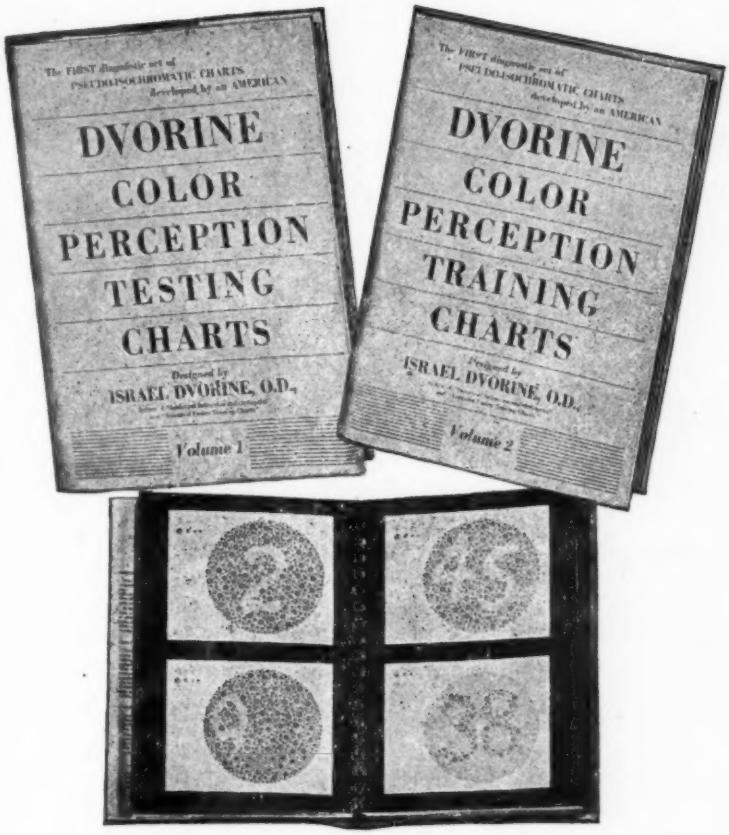

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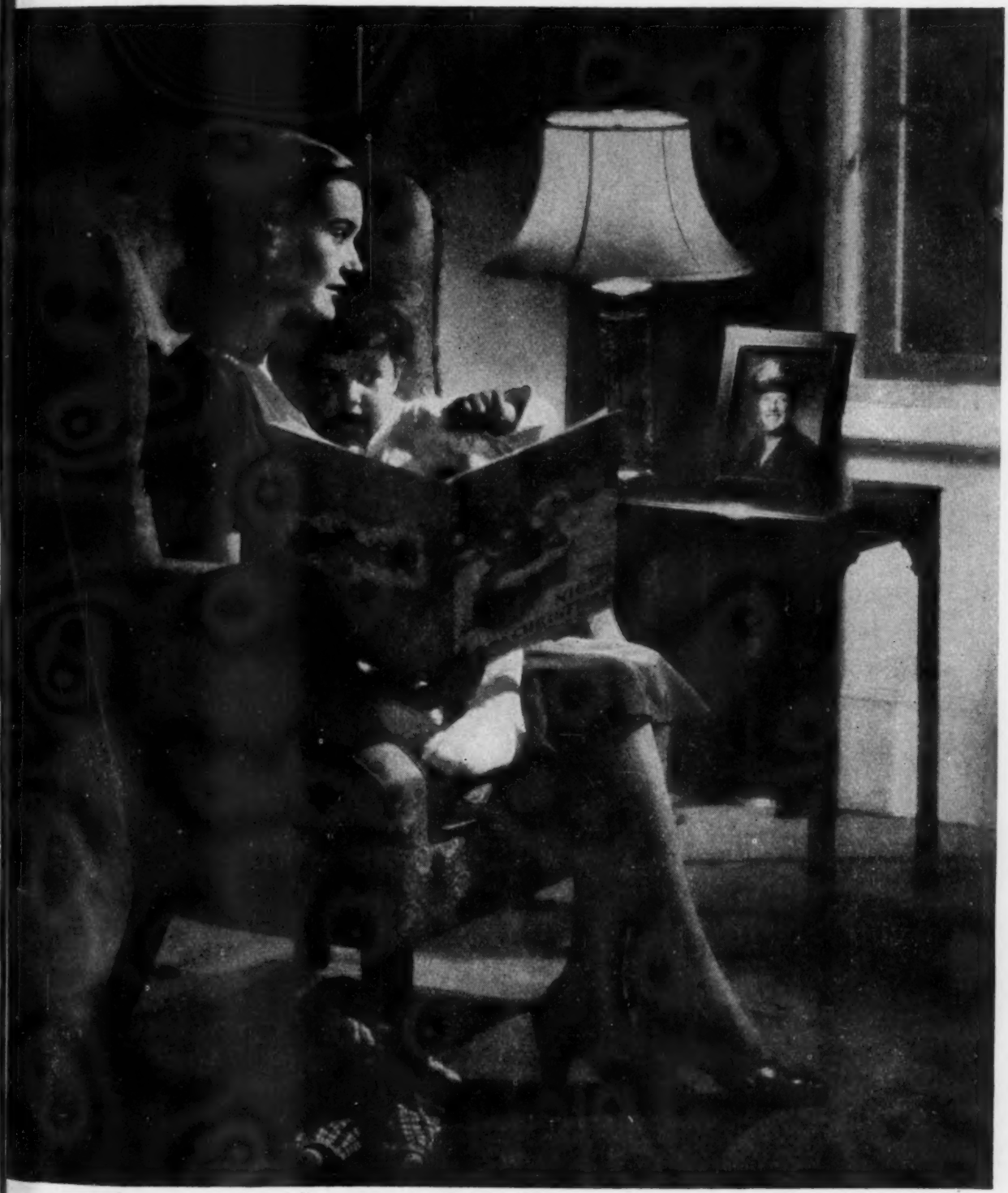

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